IMAGE PROCESSING FOR ROAD SIGNS INVENTORY

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ABSTRACT

In this paper a detection road sign system, based on the analysis of colour images, is presented. This system aims at recovering the images regions that have colours similar to those present in road signs (red, white, black, blue).

For each colour and inside adequate colour space, heuristic threshold decision are identified. Dynamic thresholds don't suffer from the illumination change effects of the whole recorded sequence. Actually the recording carried out in this procedure preparation phase were performed during the day and during good visibility conditions.

The binary images (afterwards thresholding) are associated so as to derive colour combination that are present inside the different road signs class. The check of regions size is carried out. The procedure disregards signs shape. Even if the system suggested doesn't work in real time, we optimize performance velocity for every image size and for every camcorder now available.

Road authorities, who often do not have enough reliable information about their actual road sign inventory, could use the results of images analysis for the purpose of inventory, inspection and maintenance.

Keywords: Road sign, image analysis, road signs inventory

1. INTRODUCTION

The regular and safe traffic flow is influenced either by planimetric and altimetrical composition of the road axis or by adequacy, congruence and coherence of the information sent to the driver from the road signs system. Signs message must be clearly read and interpreted so as to the road user carries out, without doubts and in advance, the actions necessary to adequate his behaviour to the received message.

Ever since eighties, several research groups proposed different algorithms for the automatic recognition of traffic signs trough the analysis of the video images recorded from camcorder mounted on board of moving vehicle.

Normally traffic signs recognition happens after two subsequent phases: detection identification and/or classification. In the first phase, the part of the images potentially containing road signs are investigated. This phase uses the following techniques: colour segmentation; corner detection and shape recognition.

A total and full reliability of the proposed procedures is not yet reached. It happens because of the difference between road signs of every regulations of the different countries, the changeable and uncontrollable environmental and lighting conditions (time, day, season, cloudiness and other weather conditions), the incorrect or inadequate signs positioning.

Referring to urban space, the rapid and unexpected evolution of the road environment (spontaneous growth of vegetation, presence of provisional public concern, posters…), the deformation of road signs and support, the natural deterioration or the vandalic change of signs surface and the environment complexity cause a further reduction in reliability.

In this paper, an automatic signs detection system is suggested. This system is based on the coincidence of the bounding box centroid, derived directly from segmentation of images trough colour and size.

By means of the association of the automatic detection procedure and the manual individuation of the images interest areas it is possible to create a signs database.

The velocity of images analysis procedure allows the Administration to check the structural and functional efficiency of the signals that more influence traffic safety and to quickly predispose the urgent maintenance interventions.

2. ITALIAN ROAD SIGNS

Road signs use particular colours, geometric shapes and size to attract drivers' attention and to allow immediate signs recognition.

In particular, the colour choice of road signs helps to guarantee an adequate chromatic contrast either between road environment and signs or between the message (text and/or picture) and the sign background.

It have to admit that this choice is not univocal. European Nations adopt in fact, for given signs typology, colours and shapes different from those provided for by American regulations.

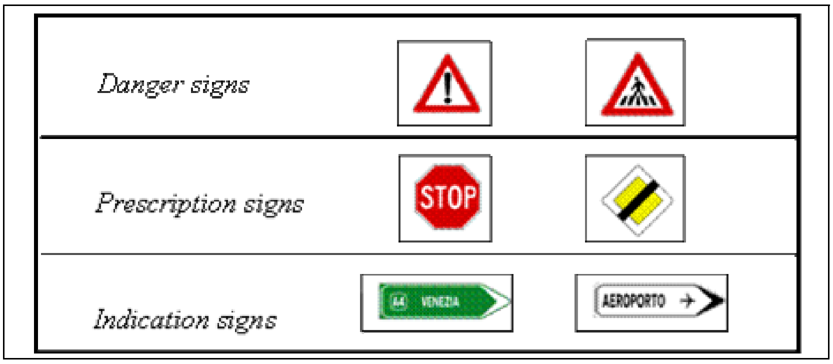


Figure 1 Italian road vertical signs

In Italy (New Traffic Code paragraph 39) road vertical signs are subdivided into (see Fig 1):

1. Danger signs;
2. Prescription signs;
3. Indication signs.

Danger signs have equilateral triangular shape with a vertex upwards. They warn drivers of a potential danger.

Prescription signs warn drivers of presence of obligation, prohibition and limitation. They are subdivided into:

- Yield signs. They have different shape: triangular, octagonal, rhomboidal.
- Prohibition signs;
- Obligation signs.

Indication signs have different shape and colour and provide information useful to individuate itinerary, resorts, public utility etc…

In order to guarantee signs visibility and legibility, signs measurements, in accordance with road type (or rather in accordance with the presumable speed) are established. The Italian regulations subdivided signs into: big, normal and small.

Besides, road sign must be located in such a way as to the sighting distance, between driver and sign, is free from obstacles. The sighting space is defined on the basis of the distance necessary to perceive and recognize a sign, to identify the meaning and to adopt the demanded behaviour. In table 1 minimum sighting distance of danger and prescription signs, on the basis of the road type, are reproduced.

Table 1 Minimum sighting distance

Road Type	Danger signs	Prescription signs
Highways and main road	150 m	250 m
Minor road and urban freeway (v>50Km/h)	100 m	150 m
Other road	50 m	80 m

In figure 2 the images of distorted and partially hidden road signs are reproduced.

Figure 2 Distorted and partially hidden road signs

3. SIGNS INVENTORY CREATION

In order to define the objectives of the image analysis useful to the signs inventory, the scheme in figure 3 is used. This scheme contemplates either the capacity either the reliability limits of image analysis procedures. The automatic recognition and the visual check of images by means of a qualified operator removes at all errors caming from the automatic non-individuation of an existing signal (there are never been recorded extractions of signal not existing). During the creation of the initial database it is assumed that the signs, perfectly identified trough the automatic procedure, must be accepted by the operator. Besides a special graphical interface allows to mark the images area that contain signs not detected trough the automatic procedure. The completion of this preliminary phase can be long and boring for the operator instead the signalling of signs anomalies (occlusions, deformations, etc…) and the update happens in the way that the Administration are fully satisfied.

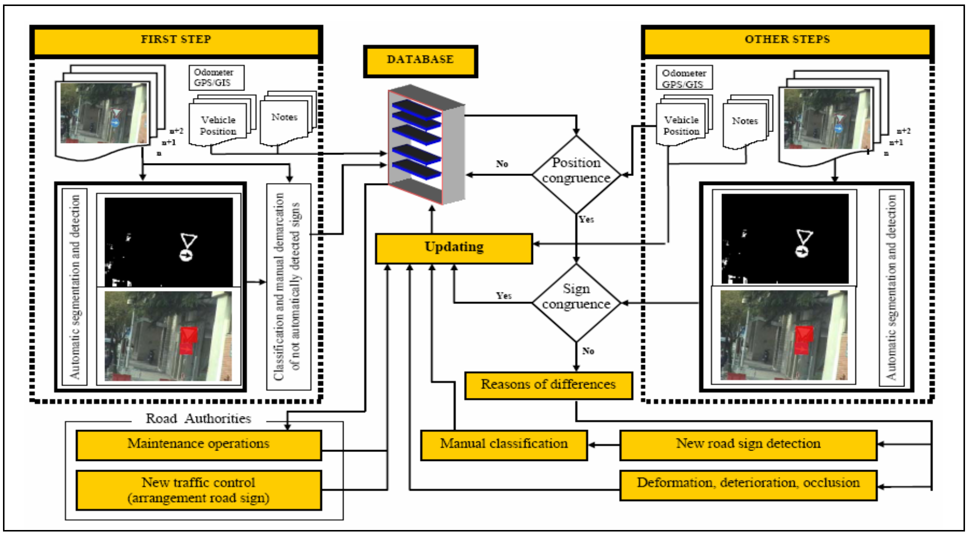


Figure 3 Scheme of signs inventory creation

4. GEOMETRY OF IMAGES FORMATION

In order to obtain geometric information about position of any object that occurs within an image, it is possible to use a pinhole camera. A generic point P (x_P, y_P, z_P) of the real scene assumes the position P*(x_{P*}, y_{P*}, z_{P*}) in the image plane (see Fig. 4).

If f is the focal length, then:

$$x_{P*}=-f\, x_P / z_P \;\; ; \;\; y_{P*}=-f\, y_P / z_P \;\; ; \;\; y_{P*}=-f$$

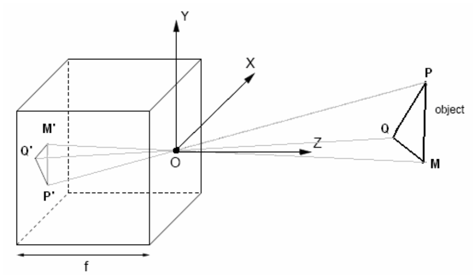


Figure 4 Projection in image plane

The reference frame (O; X,Y,Z) is integral with the pinhole lens and doesn't change his position as to the reference frame (Ω; Γ, Φ, Θ) placed in the centroid of the moving vehicle. This reference frame, however, sustains roto-translation as to a generic inertial reference frame of Cartesian axes (ω; γ, ψ, θ). The point P (x, y, z) of the observed object (road sign) doesn't change his position as to the reference frame (ω; γ, ψ, θ); the coordinates of P* in the reference frame (ω; γ, ψ, θ) depend on the position of Ω and on the rigid rotation of the reference frame (Ω; Γ, Φ, Θ) as to the axes γ, ψ, θ.

For two different camcorder positions, corresponding to two different points of vehicle trajectories (see Fig 5), the coordinates for two positions O and O' of the focal point are:

$$x_{p*} = -\frac{f x_P}{z_P} \quad ; \quad x'_{p*} = -\frac{f x'_{p*}}{z'_{p*}} = -\frac{f x'_{p*}}{z_P} \quad ; \quad x_{p*} - x'_{p*} = -\frac{f(x_P - x'_{p*})}{z_P}$$

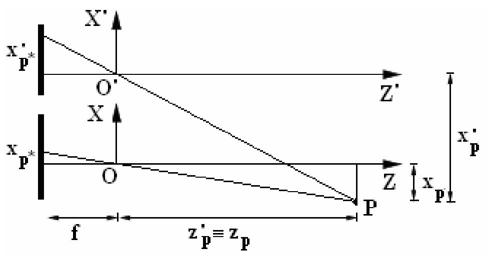


Figure 5 Two different projection

Any driver doesn't run perfectly an assigned trajectory. But it is possible to admit that the maximum deviation from an assigned trajectory is $|x'_p - x_p| \leq 1$ m and therefore $|x^*_p - x'^*_p| \leq -f/z_p$. For assigned focal distance, exist a minimum z_P value for which the perspective projection of point P is within the image limits. Camcorder focal length (defined in different way from phinole focal length) is not over about 10 mm.

It has been experimentally verified that, for the used camcorder, in case of trajectory deviation of about one meter, point P is within the image for distance z_p>15m. During the image elaboration phase, a road sign is detected also for distance along Z much more of 15 meters. Therefore possible deviations among different trajectories run by the same vehicle in different time don't prejudice the information of the recorded video-sequence. Same considerations can be done for Y because the deviation is not over 30 cm.

If the projections P', M', O' (or at least two of these) are within the image, it is possible to estimate, if the distance among the real points (P, M, Q) is known, the distance z_P if $z_P \cong z_M \cong z_Q \cong (z_P + z_M + z_Q)/3 = z$ (realistic hypothesis).

A preventive calibration of image acquisition system or a perfect optics knowledge of the utilized camcorder allows to estimate x_P and $y_{\underline{P}}$ and the centroid coordinates of the road sign (x_B, y_B, z_B) as to the reference frame (O; $\bar{X}$, Y, Z).

If on board of the vehicle an acquisition system of the vehicle position as to an assigned inertial reference frame is mounted, it is possible to approximately estimate the sign centroid coordinates (γ_B , ψ_B, θ_B) as to this reference frame.

It is possible to obtain an approximate estimation of the road sign spatial position by using the data of an easy odometer. In theory we can use different consecutives images to obtain this position. In fact, if the vehicle runs at 10 m/s (36 Km/h) and if road sign distance is between 60 e 20 m we have 75 images at camcorder acquisition velocity of 25 frames/sec.

5. COLOURS SPACE

Human perception of colours occurs afterwards a physiologic and psychologic process not yet totally explained. It is common knowledge that the human eye can point out the presence of electromagnetic waves that have frequency between 380 e 780 nanometer. Three type of photoreceptor (cones S, M, L) that are in the retina, are sensitive to three different parts of visible spectrum. Maximum sensitivity of cones is recorded on average at wavelength equal to λ_B=437 nm, λ_G=533 nm and λ_R=564 nm (corresponding respectively with blue, green and red).

In order to reconstruct the incident electromagnetic wave (colour), the brain arranges again the information came from cones and rods.

According to the tristimulus o trichromathic theory, it is possible to obtain any colour matching up the three appropriately proportionate primary colours (red, green, blue) that are previously standardized. Then it have to define the used colours space (colour model or colour system).

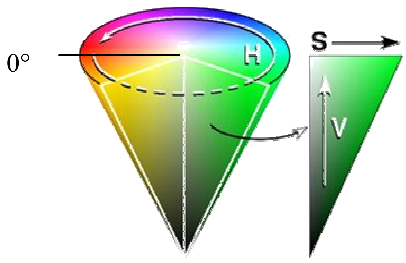
In relation to model aim and to his application (images acquisition, restitution, transmission, compression, analysis and elaboration), several colours models have been suggested. The most famous colours space is known with the abbreviation RGB (Red, Green, Blue). Every image pixel is defined only trough one byte of information for every R, G, B components. So for every primary colour, there are 256 possible values and 256^3 displaying colours.

In the RGB space, colours are not perceptively uniform, i.e. the closeness of the numerical values doesn't indicate necessarily the colours likeness. HSV and HIS models are natural and perceptively uniform.

During images elaboration and analysis we can use HSV (Hue Saturation Value) colours space. This allows to differentiate information about luminance and chrominance. The transformation from RGB to HSV is obtained easily in accordance with the relation:

$$H = \begin{cases} \left(\dfrac{(G-B)}{MAX-MIN} \right) \Big/ 6 & \text{if } R = MAX \\ \left(2 + \dfrac{(B-R)}{MAX-MIN} \right) \Big/ 6 & \text{if } G = MAX \\ \left(4 + \dfrac{(R-G)}{MAX-MIN} \right) \Big/ 6 & \text{if } B = MAX \end{cases}$$

$$S = \frac{MAX-MIN}{MAX};$$
$$V = MAX;$$
$$MAX = \max imum[R\ ;G\ ;B\ ];$$
$$MIN = \min imum[R\ ;G\ ;B\ ];$$



Hue (H) is an angle between 0° and 360°, Saturation (S) and value (V) are included between 0 and 1. For the subsequent elaborations, Hue is expressed by 1 byte (0-255) integer. In this metric Hue assumes values reproduced in the table 2.

Table 2 Hue Values

Colour	Angle (°)	Value
Red	0	0
Yellow	60	43
Green	120	85
Cyan	180	128
Blue	240	170
Magenta	300	213
Red	360	255

6. OUR DETECTION SYSTEM

A thorough examination of road signs colours and placing induces to analyze only the following parts of the image:

- White area surrounded by red area (circular and triangular shape);
- White area surrounded by blue area (circular and rectangular shape);
- Blue area surrounded by red area (circular shape, sum of two semicircles or four portions).

There are not been examined signs in which yellow regions are surrounded by white.

In order to create road signs inventory, the results are always verified by a supervisor; therefore the automatic non - identification of the signs doesn't require error for the signs database. It have to remark that any sign of this type is along the survey road stretch.

In order to differentiate red, blue and white regions, the images of three different video sequences (two in urban area and one in suburban area) are analyzed.

Afterwards several processing, working in RGB and HSV colours space, the heuristic result of colour segmentation is obtained trough the rules reproduced in table 3

Table 3 Rules of colour segmentation

Demanded Colour	Colour Space	Rules	
Red	HSV	H_{TR} if H>180 and S> T_o	
Blue	HSV	H_{TB} if 140>H>180 and S> T_o	
White	RGB	R_T=R>T_o	W=Max(R_T, G_T, B_T)
	RGB	G_T=G>T_o	
	RGB	B_T=B>T_o	

In table 3 the generic To value characterizes threshold value obtained using Othu's method (unsupervised and non parametric) to the numerical value in the considered canal. If the intensity of every class is Gaussian, To value is obtained minimizing the variance within class or maximizing the variance between class. This method provides an excellent value only if the distribution is bimodal and each class has approximately the same number of values. In this application, even if some canals have plurimodal intensity histogram, the method always comes up to the expectations.

The red, blue and white binary matrix ($\mathbf{H_{TR}}$, $\mathbf{H_{TB}}$ **W**) have been handled so as to link pixel close but not connected. In order to carry out the close morphological operation an adequate kernel (Minkowski sum and difference) has been utilized. The obtained matrices are respectively $\mathbf{H_R}$ and $\mathbf{H_B}$.

The intersection between matrices $\mathbf{H_R} \otimes \mathbf{W= W_R^*}$, $\mathbf{H_B} \otimes \mathbf{W= W_B^*}$, $\mathbf{H_R} \otimes \mathbf{H_B=W_{RB}^*}$ identifies respectively white regions surrounded by red, white regions surrounded by blue, blue regions surrounded by red.

The elements of matrices $\mathbf{W_R^*}$, $\mathbf{W_B^*}$,$\mathbf{W_{RB}^*}$ that have value 1 can belong to the projection of a road sign on the image plane. The regions of these matrices are closed and connected.

For each bounding box of these regions we calculated the pixel of height (h), width (l), surface (A=h*l), and the ratio R=h/l. Owing to the real size of signs, the previous quantity have to be limited within prefixed value. These limits depend on the image original size and distance z_{min} e z_{max} (between camcorder and sign). In fact the sign looks too small if the distance is higher than z_{max}; too big if the distance is less than z_{min}.

Finally the centroid position of the regions that are in the following couple of matrices $\mathbf{W_R^*}$-$\mathbf{H_R}$, $\mathbf{W_B^*}$-$\mathbf{H_B}$, $\mathbf{W_{RB}^*}$-$\mathbf{H_B}$ are compared. For a road sign, the centroid distance must be zero or almost zero.

A picture of the steps performed during processing is reproduced in figure 6.

In order to verify that the shape of the objects found is compatible with the real sign, the regions that have pass previous selection must be analyzed.

In order to determine the shape of these objects different algorithms are available.

It have to remark that the procedure suggested only supplied regions that really contain a road sign.

The signs identification and classification is entrusted to the operator (see Fig 3). An automatic classification of signs also needs the recognition of black ideograms. The procedure provides a special algorithm useful to close the holes of the different regions (if the morphological operation are not successfull).

The procedure also utilizes algorithms for signs tracking. In this way the operator task is much reduced. The same sign, present in n images, appears just once for the recognition.

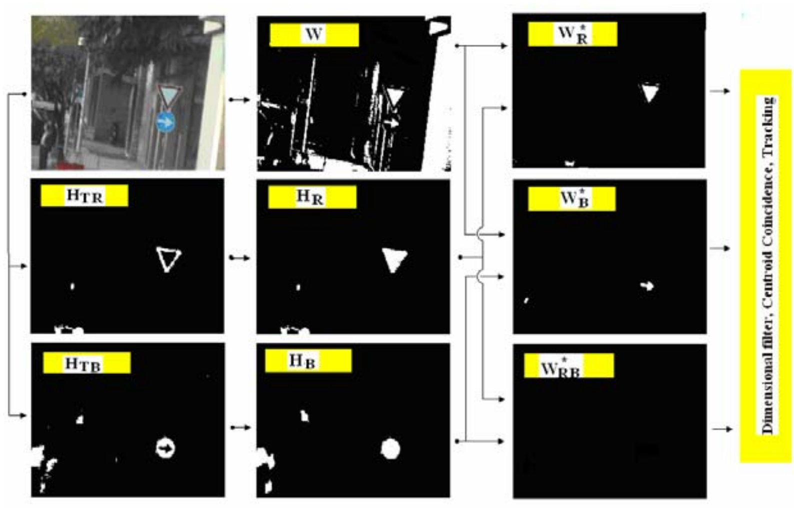


Figure 6 Processing Steps

7. PROCEDURE PERFORMANCE

The percentage of visible and not-visible road signs are reproduced in table 4.

Table 4 Procedure results

	Urban Way 1	UrbanWay 2	Suburban Way 1
Detected whole signs	98,47	98,26	96,71
Partially visible detected signs	10,09	11,42	3,29

During the urban ways, visible road signs are 631. Images elaboration doesn't correctly detected only two signs. It happens owing to the big alteration of red. In suburban ambit all the visible signs are completely detected.

All the ways have been run for two times. The images processing results are the same. Small differences among the trajectories of the camcorder equipped vehicle do not provide different results. Consequently the procedure is valid to the road signs inventory creation.

In urban ambit the camcorder also frames signs belonging to roads close to trajectory of moving vehicle and moreover small turn radius doesn't allow to frame correctly some signs. The employment of more camcorder can solve the problem. Anyway the procedure suggested, carrying out adequate changes, can be used.

8. CONCLUSIONS

Images analysis certainly accelerates the procedure of road signs inventory creation. Fully visible road signs are always detected and consequently easily and quickly identified and classified by the operator.

It is possible to implement algorithms for the automatic classification. But the problem of detection and classification of occluded, deformed and decolorated signs still persists. These latter signs always demand a careful visual images analysis and a long time. It is still possible to improve the algorithm of road signs detection so as to extract also not fully visible signs. This is also possible using the database information as they arrive.

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